

What is claimed is:

1. A computer program stored on a computer-readable medium for determining the printability of a defect on a reticle or photomask onto a substrate during processing of said substrate, said printability being determined from a defect review menu of said reticle or photomask prepared by an inspection machine and weighting factors related to a fabrication procedure used to produce said substrate, said computer program comprising:
 - a. instructions for creating a pixel grid image of a portion of said reticle or photomask containing said defect identified in said defect review menu, said pixel grid image having a plurality of associated individual pixel images of said reticle or photomask;
 - b. instructions for assigning a gray scale value to each of said associated individual pixel images of said pixel grid image;
 - c. instructions for selecting a probable center pixel of said defect in said pixel grid image;
 - d. instructions for determining a polarity of said defect;
 - e. instructions for determining a region of physical extent of said defect; and
 - f. instructions for determining a transmissivity energy level of said region of physical extent of said defect.
2. The computer program of claim 1 wherein said gray scale values have a range from 0 to 256, with 0 representing an opaque pixel and 256 representing a totally transmissive pixel.
3. The computer program of claim 1 wherein:
instructions c. include:
 - g. instructions for noting coordinates of said probable center pixel from said defect review menu; and

instructions d. include:

h. instructions for selecting a reference pixel from said defect review menu with said reference pixel spaced-apart from said probable center pixel and not included in said region of physical extent of said defect;

i. instructions for assigning a gray scale value to said reference pixel;

j. instructions for comparing said gray scale value of said reference pixel with said gray scale value of said probable center pixel; and

k. instructions for assigning a polarity of white to said region of physical extent of said defect if said gray scale value of said probable center pixel is greater than said gray scale value of said reference pixel, or a polarity of black to said region of physical extent of said defect if said gray scale value of said probable center pixel is less than said gray scale value of said reference pixel.

4. The computer program of claim 1 wherein:

instructions c. include:

g. instructions for noting coordinates of said probable center pixel from said defect review menu; and

instructions d. include:

h. instructions for selecting a plurality of reference pixels from said defect review menu with each of said plurality of reference pixels spaced progressively further apart from said probable center pixel in the same direction;

i. instructions for assigning a gray scale value to each of said plurality of reference pixels;

j. instructions for comparing said gray scale value of each of

said plurality of said reference pixels with said gray scale value of said probable center pixel, and said gray scale value of each reference pixel and each other reference pixel adjacent thereto; and

5 k. instructions for assigning a polarity of white to said region of physical extent of said defect if said gray scale value of each of said plurality of reference pixels successively decreases from said gray scale value of said probable center pixel as the spacing from said probable center pixel increases; or a polarity of black to said region of physical extent of said defect if said gray scale value of each of said plurality of reference pixels successively increases from said gray scale value of said probable center pixel as the spacing from said probable center pixel increases; or if the difference between said gray scale value of said probable center pixel and each of said plurality of references pixels varies in one direction and then in an opposite direction the further from said probable center pixel said reference pixel is located, said probable center pixel is probably located in close proximity to a line edge on said reticle or photomask requiring that said plurality of references pixels be
10 reselected in a different direction from said probable center pixel in order to determine polarity of said region of physical extent of said defect and steps h., i. and j. repeated until a polarity determination for said region of physical extent of said defect can be made.

5. The computer program of claim 1 wherein instructions e. include:

g. instructions for selecting a minimum threshold value of a
25 difference in gray scale values between adjacent pixels to define an edge of said region of physical extent of said defect;

h. instructions for noting said gray scale value for said probable center pixel of said defect;

i. instructions for selecting a direction beginning with said probable

center pixel in which to search for said edge of said region of physical extent of said defect;

j. instructions for calculating a difference in gray scale values of juxtaposed pixels in said selected direction starting with said probable center pixel

5 until the magnitude of said difference in gray scale values first exceeds said threshold;

k. instructions for setting said edge of said region of physical extent of said defect in the selected direction as a boundary between said juxtaposed pixels where said threshold level is exceeded; and

l. repeating instructions i. through k. in numerous selected
10 directions from said probable center pixel to define said physical extent of said defect in said selected directions.

6. The computer program of claim 1 wherein instructions f. include:

g. instructions for summing together said gray scale values of all of
15 said pixels included within said physical extent of said defect to determine an initial measure of an energy level of said defect; and

h. instructions for subtracting a background energy level from said initial measure of an energy level to determine said transmissivity energy level of said region of physical extent of said defect.

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7. The computer program of claim 6 wherein instructions h. include:

i. instructions for selecting a region adjacent said region of physical extent of said defect on said reticle or photomask having the same size and shape as said region of physical extent of said defect;

25 j. instructions for summing together gray scale values of all pixels included within said adjacent region to determine a background energy level of said reticle or photomask; and

k. instructions for subtracting said background energy level from said initial measure of an energy level to determine said transmissivity energy level of

said region of physical extent of said defect.

8. The computer program of claim 7 wherein said adjacent region of instructions i. is defect free.

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9. The computer program of claim 6 wherein instructions h. include:

i. instructions for selecting a plurality of regions adjacent said region of physical extent of said defect on said reticle or photomask, each selected region having the same size and shape as said region of physical extent of said

10 defect;

j. instructions for summing together gray scale values of all pixels included within each of said plurality of adjacent regions separately;

k. instructions for averaging together each of said gray scale value sums to determine a background energy level of said reticle or photomask; and

15 l. instructions for subtracting said background energy level from said initial measure of an energy level to determine said transmissivity energy level of said region of physical extent of said defect.

10. The computer program of claim 1 further includes:

20 g. instructions for determining printability of said defect by applying a weighting factor to said transmissivity energy level, said weighting factor being a combination of several variables contributed by a particular wafer fabrication process being used to produce a substrate using said reticle or photomask.

25 11. The computer program of claim 1 between instructions d. and e. further includes:

g. instructions for determining a coarse center pixel of said defect using said probable center defect and said polarity of said defect.

12. The computer program of claim 1 wherein instructions g. include:

h. instructions for comparing said gray scale value of said probable center pixel individually with said gray scale of each pixel juxtaposed to said probable center pixel;

5 i. instructions for determining if said polarity of said defect is white and step h. reveals a pixel juxtaposed to said probable center pixel that has a higher gray scale value than said gray scale value of said probable center pixel, said juxtaposed pixel is selected as said coarse center pixel of said defect;

j. instructions for determining if said polarity of said pixel grid image
10 is black and step h. reveals a pixel juxtaposed to said probable center pixel that has a lower gray scale value than said gray scale value of said probable center pixel, said juxtaposed pixel is selected as said coarse center pixel of said defect;

k. instructions for repeating instructions h. through j. if instructions i. or j. resulted in the selection of a different coarse center pixel; and

15 l. instructions for selecting a last selected coarse center pixel as said coarse center pixel following the last performance of instructions k., or selecting said probable center pixel as said coarse center pixel if an initial performance of neither instructions i. nor j. resulted in the selection of a different coarse center pixel.

20 13. The computer program of claim 11 wherein instructions e. include:

h. instructions for selecting a minimum threshold value of a difference in gray scale values between adjacent pixels to define an edge of said region of physical extent of said defect;

25 i. instructions for noting said gray scale value for said coarse center pixel of said defect;

j. instructions for selecting a direction beginning with said coarse center pixel in which to search for said edge of said region of physical extent of said defect;

k. instructions for calculating a difference in gray scale values of juxtaposed pixels in said direction selected in step j. starting with said coarse center pixel until the magnitude of said difference in gray scale values first exceeds said threshold;

5 l. instructions for setting said edge of said region of physical extent of said defect in the direction selected in instructions j. as a boundary between said juxtaposed pixels identified in instructions k. where said threshold level is exceeded; and

m. instructions for repeating instructions j. through l. in numerous
10 selected directions from said coarse center pixel to define said physical extent of said defect in said selected directions.

14. The computer program of claim 11 between instructions g. and e. includes:

15 h. instructions for determining a fine center of said defect using said coarse center pixel and said polarity of said defect.

15. The computer program of claim 14 wherein:
instructions g. include:

20 i. instructions for comparing said gray scale value of said probable center pixel individually with said gray scale of each pixel juxtaposed to said probable center pixel;

j. instructions for determining if said polarity of said defect is white and instructions i. reveal a pixel juxtaposed to said probable
25 center pixel that has a higher gray scale value than said gray scale value of said probable center pixel, said juxtaposed pixel is selected as said coarse center pixel of said defect;

k. instructions for determining if said polarity of said pixel grid image is black and instructions i. reveal a pixel juxtaposed to said

probable center pixel that has a lower gray scale value than said gray scale value of said probable center pixel, said juxtaposed pixel is selected as said coarse center pixel of said defect;

l. instructions for repeating instructions i. through k. if instructions j. or k. resulted in the selection of a different coarse center pixel; and

m. instructions for selecting a last selected coarse center pixel as said coarse center pixel following the last performance of instructions l., or selecting said probable center pixel as said last coarse center pixel if an initial performance of neither instructions j. nor k. resulted in the selection of a coarse center pixel; and

instructions h. include:

n. instructions for determining a fine center of said defect using a subpixel interpretation routine on said coarse center pixel.

16. The computer program of claim 15 wherein instructions n. include:

o. instructions for selecting said coarse center pixel and a first and a second pixel each juxtaposed, and on opposite sides of, said coarse center pixel, with said three pixels defining a first straight line;

p. instructions for summing said gray scale values of each of said coarse center pixel and said first and second juxtaposed pixels;

q. instructions for summing said gray scale value of said first juxtaposed pixel with twice said gray scale value of said coarse center pixel and with three times said gray scale value of said second juxtaposed pixel;

r. instructions for dividing a result of instructions q. by a result of instructions p. to yield a value having a whole number portion and a fractional number portion,

wherein if said whole number portion is 1 said fine center

of said defect is spaced-apart from said coarse center pixel toward said first juxtaposed pixel by said fractional number portion of a pixel width along said first straight line, and wherein if said whole number portion is 2 said fine center of said defect is spaced-apart from said coarse center pixel toward said second juxtaposed pixel by said fractional number portion of a pixel width along said first straight line;

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10 s. instructions for selecting said coarse center pixel and a third and a fourth pixel each juxtaposed, and on opposite sides of, said coarse center pixel, with said three pixels defining a second straight line;

t. instructions for summing said gray scale values of each of said coarse center pixel and said third and fourth juxtaposed pixels;

15 u. instructions for summing said gray scale value of said third juxtaposed pixel with twice said gray scale value of said coarse center pixel and with three times said gray scale value of said fourth juxtaposed pixel;

v. instructions for dividing a result of instructions u. by a result of instructions t. to yield a value having a whole number portion and a fractional number portion,

20 wherein if said whole number portion is 1 said fine center of said defect is spaced-apart from said coarse center pixel and said third juxtaposed pixel by said fractional number portion of a pixel width along said second straight line, and wherein if said whole number portion is 2 said fine center of said defect is spaced-apart from said coarse center pixel and said fourth juxtaposed pixel by said fractional number portion of a pixel width along said second straight line; and

25 w. instructions for determining a point of intersection between said first and second straight lines with said point of intersection being said fine center of

said defect on said reticle or photomask.

17. The computer program of claim 14 wherein instructions e. include:

- 5 i. instructions for selecting a minimum threshold value of a difference in gray scale values between adjacent pixels to define an edge of said region of physical extent of said defect;
- j. instructions for noting said gray scale value for a pixel in which said fine center of said defect is located;
- 10 k. instructions for selecting a direction beginning with said fine center of said defect in which to search for said edge of said region of physical extent of said defect;
- l. instructions for calculating a difference in gray scale values of juxtaposed pixels in said direction selected in step k. starting with said pixel in which
- 15 said fine center of said defect is located until the magnitude of said difference in gray scale values first exceeds said threshold;
- m. instructions for setting said edge of said region of physical extent of said defect in the direction selected in step k. as a boundary between said juxtaposed pixels identified in step l. where said threshold level is exceeded; and
- 20 n. instructions for repeating instructions k. through m. in numerous directions from said pixel in which said fine center of said defect is located to define said physical extent of said defect in said selected directions.

18. The computer program of claim 1 further includes:

- 25 g. instructions for determining proximity of said defect to an edge of a pattern on said reticle or photomask using said region of physical extent said defect and said polarity of said defect.

19. The computer program of claim 18 wherein instructions g.

include:

- h. instructions for searching said defect review menu of said reticle or photomask in a selected direction outside said region of physical extent of said defect for pixels having a gradient of gray scale values that successively and rapidly
5 approach an opposite polarity from that of said defect;
- i. instructions for determining a difference of gray scale values of said gradient between pixels having the greatest and least gray scale values;
- j. instructions for performing sub-pixel interpolation on pixels defining said gradient to determine a transition pixel location where said gradient has
10 a gray scale value half-way between said greatest and least gray scale values of said gradient with said location being a point on an edge of said pattern on said reticle or photomask; and
- k. instructions for measuring a distance between said point of an edge and said probable center pixel with said measured distance being a distance
15 from said edge of said pattern on said reticle or photomask and said defect in said selected direction.

20. The computer program of claim 19 further includes:

- l. instructions for repeating instructions h. through k. for additional
20 directions outside said region of physical extent of said defect to determine proximity of said defect to additional points on edges on said reticle or photomask.

21. The computer program of claim 18 further includes:

- h. instructions for selecting a threshold transmissivity level above
25 which said defect is deemed printable;
- i. instructions for determining a primary weighting factor from said region of physical extent of said defect and several variables of a particular wafer fabrication process being used to produce said substrate;
- j. instructions for determining a secondary weighting factor based

on said proximity of said defect to a point on an edge of a pattern on said reticle or photomask;

k. instructions for combining said primary weighting factor and said secondary weighting factor;

5 l. instructions for applying said combined weighting factors to said transmissivity energy level to determine an effective transmissivity energy level of said defect; and

m. instructions for comparing said effective transmissivity energy level to said threshold transmissivity level with said defect being printable if said
10 effective transmissivity energy level exceeds said threshold transmissivity level.

22. The computer program of claim 21 wherein said secondary weighting factor is selected to produce an effective transmissivity energy level that is higher the closer said defect is to a point on an edge of a pattern on said reticle or
15 photomask as opposed to defects that are not in close proximity to an edge on said reticle or photomask.

23. A computer program stored on a computer-readable medium for determining the printability of a defect on a reticle or photomask onto a substrate
20 during processing of said substrate, said printability being determined from a defect review menu of said reticle or photomask prepared by an inspection machine and weighting factors related to a fabrication process used to produce said substrate, said computer program comprising:

a. instructions for creating a pixel grid image of a portion of said
25 reticle or photomask containing said defect identified in said defect review menu, said pixel grid image having a plurality of associated individual pixel images of said reticle or photomask;

b. instructions for assigning a gray scale value to each of said associated individual pixel images of said pixel grid image;

- c. instructions for selecting a probable center pixel of said defect in said pixel grid image;
 - d. instructions for determining a polarity of said defect;
 - e. instructions for determining a coarse center pixel of said defect
 - 5 using said probable center defect from and said polarity of said defect;
 - f. instructions for determining a fine center of said defect using said coarse center pixel and said polarity of said defect;
 - e. instructions for determining a region of physical extent of said defect;
 - 10 f. instructions for determining a transmissivity energy level of said region of physical extent of said defect;
 - g. instructions for determining proximity of said defect to an edge of a pattern on said reticle or photomask using said region of physical extent of said defect and said polarity of said defect; and
 - 15 h. instructions for determining printability of said defect by applying a weighting factor to said transmissivity energy level, said weighting factor being a combination of several variables contributed by a particular wafer fabrication process being used to produce said substrate using said reticle or photomask.
- 20 24. The computer program of claim 23 wherein instructions h. include:
- i. instructions for selecting a threshold transmissivity level above which said defect is deemed printable;
 - j. instructions for determining a primary weighting factor from said
 - 25 region of physical extent of said defect and several variables of a particular wafer fabrication process being used to produce said substrate;
 - k. instructions for determining a secondary weighting factor based on said proximity of said defect to an edge of a pattern on said reticle or photomask;
 - l. instructions for combining said primary weighting factor and said

secondary weighting factor;

m. instructions for applying said combined weighting factors to said transmissivity energy level to determine an effective transmissivity energy level of said defect; and

5 n. instructions for comparing said effective transmissivity energy level to said threshold transmissivity level with said defect being printable if said effective transmissivity energy level exceeds said threshold transmissivity level.

25. The computer program of claim 24 wherein said secondary
10 weighting factor is selected to produce an effective transmissivity energy level that is higher the closer said defect is to a point on an edge of a pattern on said reticle or photomask as opposed to defects that are not in close proximity to an edge on said reticle or photomask.

15